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(54) Geophone with shaped magnetic field

(57) Two or more magnets 26, 22, 27 are used to produce the high flux density magnetic field through which a coil 40 moves whereby the output signal of the geophone is increased. The auxiliary magnet or magnets (i.e. 26, 27) may be ring-shaped and two separate moving coils may be used.

FIG. 1

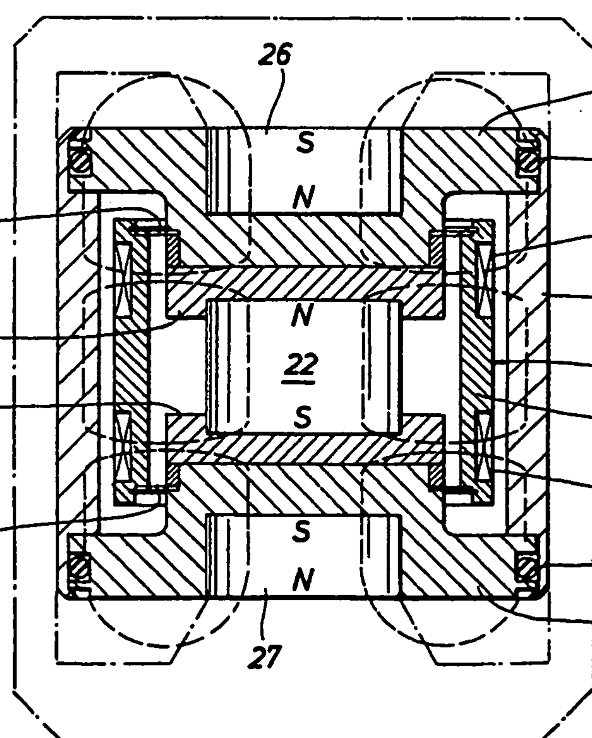

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FIG.1

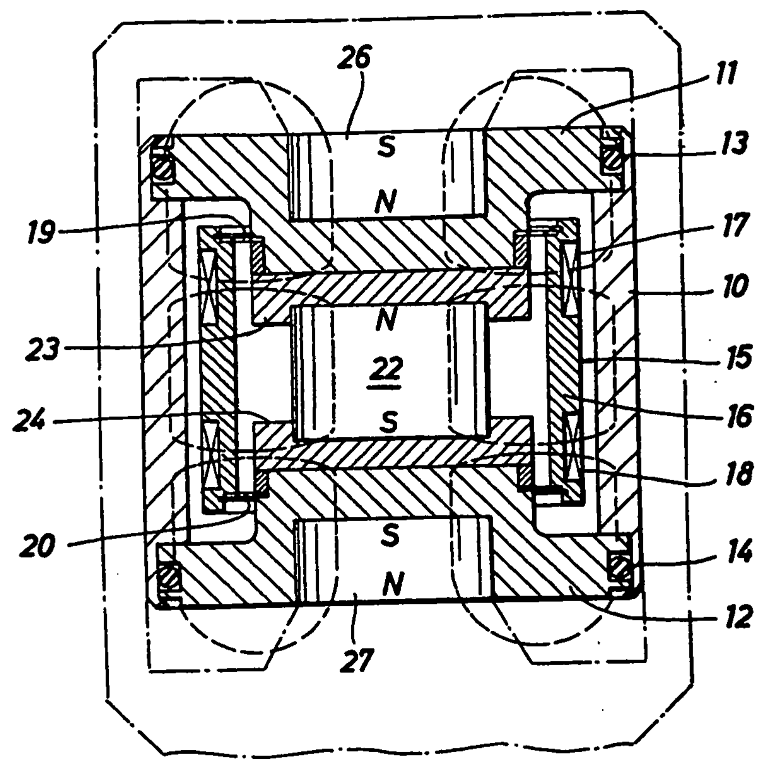
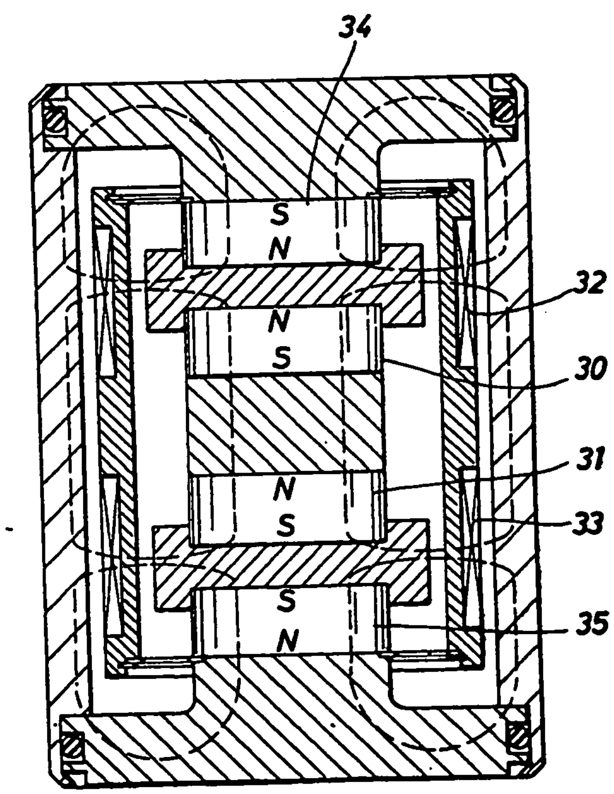


FIG.2



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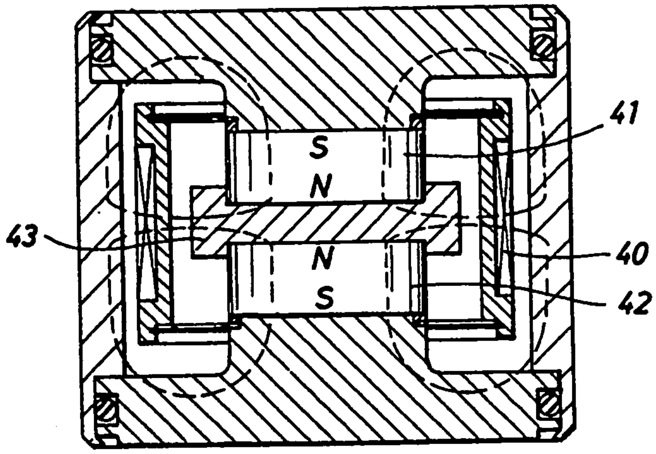

FIG. 3

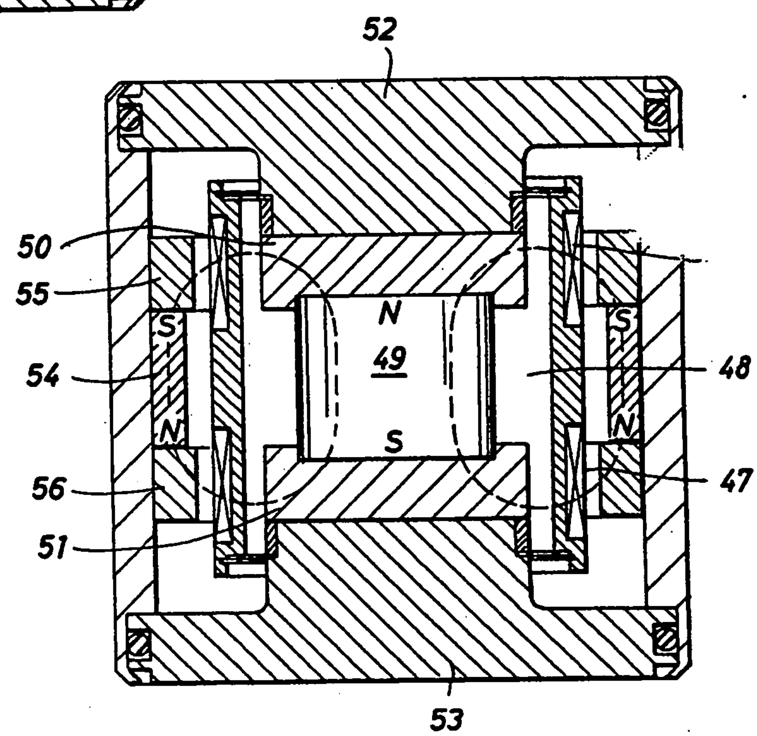

FIG. 4

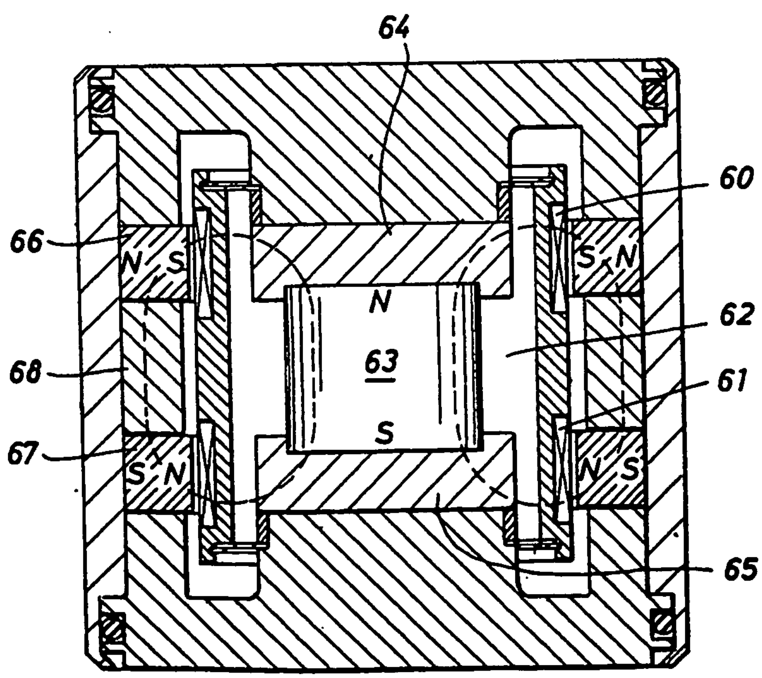

FIG. 5

SPECIFICATION

Geophone with shaped magnetic field

This invention relates to geophones generally and in particular to geophones of the type that employ a moving coil in a magnetic field to detect earth movements.

This invention has utility with any geophone or seismometer, as they are sometimes called, that employs a moving coil in a magnetic field to measure the earth's movement. This type of geophone is generally referred to as the electromagnetic type. It consists of a coil and a magnet, one rigidly fixed with respect to the earth and the other suspended from a spring for movement relative to the earth fixed element. Any relative motion between the coil and magnet due to movement of the earth and the inertia of the movable element produces an electromotive force across the terminal of coil that is proportional to the velocity of the motion. The most common arrangement is for the coil to constitute the inertial element. The bobbin on which the coil is wound (the bobbin and coil assembly is usually referred to as the coil-mass) is supported in the geophone housing by springs. Usually the springs used are of the spring-spider type, which are circular springs, or disc-type springs, that are particularly useful in supporting the annular shaped coil-mass assembly. The magnet that produces the magnetic field is usually mounted inside the annular coil-mass assembly and is fixed relative to the housing of the geophone. The sensitivity of this type of geophone depends on the strength of the magnetic field through which the coil moves and, of course, the number of turns in the coil.

Pole pieces and other elements of a material that is highly permeable to magnetic flux are located in position to conduct the magnetic field of the magnet in the desired direction but there is inherently an air gap through which the magnetic field of the magnet must travel as it leaves the magnet. Magnetic flux traveling into an air gap inherently occupies a greater area than it would in a highly permeable metal and, therefore, there is a fringing out of the flux causing a leakage of flux and a diminishing in the strength of the magnetic field through which the coil moves.

It is an object of this invention to so shape the magnetic field of the geophone that the flux density of the field through which the coil moves is increased thereby increasing the output signal of the geophone.

It is a further object of this invention to provide a geophone having magnets positioned so that the magnetic field of the geophone is shaped by the positioning of the magnets to cause the flux density to be increased in the area through which the coil of the geophone moves.

It is a further object of this invention to provide a geophone having a plurality of magnets arranged to attract and/or repel the magnetic fields of the magnets to cause the density of the flux traveling through the area where the coil is located to be substantially increased.

These and other objects, advantages, and features of this invention will be apparent to those skilled in the art from a consideration of this specification, including the attached drawings and appended claims.

FIGURE 1 is a sectional view through a geophone embodying the invention and which employs the repelling characteristics of the magnet to shape the magnetic flux travelling through the coil of the geophone to provide an increase in flux in that area.

FIGURE 2 is a cross-sectional view of an alternate embodiment of the invention of this application.

FIGURE 3 is another cross-sectional view showing another alternate embodiment of the invention.

FIGURE 4 is a cross-sectional view of a geophone embodying another alternate embodiment of this invention.

FIGURE 5 is an alternate embodiment of the invention.

In the drawings, FIGURES 1 through 5 are cross-sectional views of geophones incorporating alternate embodiments of the invention, wherein the magnets are arranged to shape the magnetic field of the geophone to increase the flux density of the field in the area through which the coil of the geophone moves.

In FIGURE 1, annular housing 10 is closed at each end by end members 11 and 12. The ends of the housing are crimped over the end members to hold them in place, as shown. O-rings 13 and 14 seal the inside of housing 10. Coil-mass assembly 15 includes annular bobbin 16 and coils 17 and 18, which are wound on the bobbin. Coil-mass assembly 15 is supported by spring spiders 19 and 20 from end members 11 and 12 respectively, as shown. The spring spiders allow the coil-mass assembly to move relative to the housing and the end members along the longitudinal axis of the housing of the geophone.

Positioned between end members 11 and 12 is permanent magnet 22. Between the ends of the magnet, which is circular in cross-section, and the end members are pole pieces 23 and 24. Preferably, the pole pieces are made of a material that is highly permeable to magnetic flux. Pole pieces 23 and 24 are positioned in the conventional manner to tend to conduct the magnetic field produced by magnet 22 toward the air gap between the pole pieces and the housing 10 where coils 17 and 18 are located. The magnetic field produced by magnet 22, however, moves through and out of the pole pieces in all directions resulting in a fringing out of the flux after it leaves the magnet.

In accordance with this invention, magnets 26 and 27 are positioned in end pieces 11 and 12 respectively, as shown, to shape the magnetic field of the magnets to increase the flux density present in the air gap through which the coils travel. In this embodiment this is accomplished by positioning magnets 26 and 27 with their poles such that they oppose the adjacent poles of magnet 22. In other words, magnet 26 is positioned with its north pole adjacent or facing the north pole of magnet 22 and the south pole of magnet 27 is in position to oppose or repel the south pole of magnet 22. With this arrangement, the magnetic flux coming out of magnet 22 and returning thereto will be repelled by the magnetic field of magnets 26 and 27 and forced to travel laterally, as

shown by the dotted lines, through pole piece 23 into the air gap in which coil 17 is located, then through housing 10 and back through the air gap where coil 18 is located to pole piece 24. The result is a substantial increase in the flux density in the air gap at the coils and, consequently, an increase in the output signal of the geophone. In this embodiment, the magnetic field of the geophone is shaped by employing the repelling effect of magnets to cause the increase in flux in the area of the coils of the geophone.

The embodiments shown in FIGURES 2 through 5 constructed in substantially the same manner as that described and shown in FIGURE 1 and, therefore, they will not be described in detail.

In the embodiment shown in FIGURE 2, the magnetic field of the geophone is shaped by arranging magnets to use the same repelling effect as described above to cause an increase in the flux density in the air gap in which the coil is located. In this embodiment magnets 30 and 31 are positioned so that their magnetic fields attract and provide the magnetic field in the air gap in which are located coils 32 and 33 of the geophone. Magnets 34 and 35 are positioned with their poles arranged to oppose the field created by magnets 30 and 31 and, as explained above, urge the magnetic field produced by magnets 30 and 31 to move laterally through the air space in which coils 32 and 33 are located. Again the effect is to increase the flux density in which the coils are positioned and through which they travel, thereby improving the signal output of the geophone.

FIGURE 3 is another example of using magnets arranged with their fields in opposing positions to shape the magnetic field of the geophone so that the flux density in the space occupied by the coil is increased. In this embodiment the geophone is shown as having one coil 40. Magnets 41 and 42 are positioned on opposite sides of pole piece 43 with their poles in opposing relationship to cause the magnetic fields of each magnet to be repelled by the other magnet with the result that the combined magnetic fields of the magnets move laterally through the pole piece 43 and into the air gap in which coil 40 is located. The result is an increase in the flux density in the area of the coil produced by the magnetic fields of the two magnets.

The embodiments in FIGURES 4 and 5 employ the attraction between opposite poles of magnets to shape the magnetic field to increase the flux density through the air gap in which the coils are located. In FIGURE 4 spaced coils 46 and 47 are positioned in annular air gap 48 surrounding magnet 49. Pole pieces of highly permeable material 50 and 51 are positioned on opposite ends of magnet 49. Preferably, end members 52 and 53 are made of a material having a very low permeability to magnetic flux to tend to cause the magnetic flux of magnet 49 to flow laterally from the poles through the pole pieces. Annular magnet 54 is located on the opposite side of coils 46 and 47 from magnet 49. Annular pole pieces of highly permeable material 55 and 56 are positioned on opposite sides of annular magnet 54. Annular magnet 54 is positioned with its poles in opposite positiones from that of magnet 49. In the embodiment shown, for example, the north pole of magnet 49 is on the upper end as shown, therefore, the south pole of magnet 54 is positioned with its south pole looking upwardly, as shown in FIGURE 4. With this arrangement the magnetic fields of the two magnets attract each other and the position of magnet 54 will tend to pull the magnetic flux of magnet 49 from pole piece 50 to pole piece 55 and then completing the circuit through pole piece 56 to pole piece 51 and back to the south pole of magnet 49. This results in an increase in the flux density in gap 48 in which are located coils 46 and 47.

The embodiment of FIGURE 5 employs a similar arrangement as that described in connection with FIGURE 4. Here two longitudinally spaced coils 60 and 61 are supported for movement in air space 62. The air space is annular extending around centrally mounted magnet 63. Pole pieces 64 and 65 of highly permeable material are positioned on opposite ends of magnet 63 in the same manner as in FIGURE 4. Extending around air gap 62 and coils 60 and 61 are two annular magnets 66 and 67. These magnets are magnetized so that one pole is adjacent the inside surface of the annular magnet and the other pole is adjacent the outside surface of the magnet, as shown in FIGURE 5. Annular spacer or pole piece 68 of highly permeable material is positioned between the magnets. Here again, as in the embodiment described in FIGURE 4, the poles of the magnets are positioned so that they tend to attract and enhance the magnetic field produced by the magnets. For example, in FIGURE 5, the north pole of 63 is the upper end of the magnet and the south pole is on the lower end. The south pole of magnet 66 is positioned to attract the magnetic flux emminating from the north pole of magnet 63 and pull the flux through air gap 62 through the area occupied by coil 60. In the same manner the north pole of magnet 67 is positioned so that the flux path between the south pole of magnet 63 and magnet 67 is shaped to move through the air gap occupied by coil 61 which results in both instances with an increase in the flux density in the air gap where the coils are located and an improved output signal for the geophone.

From the foregoing, it will be seen that this invention is one well adapted to attain all of the ends and objects hereinabove set forth, together with other advantages which are obvious and which are inherent to the apparatus and structure.

It will be understood that certain features and sub-combinations are of utility and may be employed without reference to other features and subcombinations. This is contemplated by and is within the scope of the claims.

As many possible embodiments may be made of this invention without departing from the scope thereof, it is to be understood that all matter herein set forth or shown in the accompanying drawings is to be interpreted as illustrative and not in a limiting sense.

CLAIMS

1. A geophone comprising a permanent magnet assembly and a coil movable through the magnetic field of the magnet assembly to produce a signal,

said magnet assembly including at least two magnets positioned to provide a magnetic field through which said coil moves, said magnets being positioned with their magnetic poles arranged to increase the flux density of the magnetic field through which the coil moves relative to the magnet.

2. The geophone of claim 1 in which the magnet assembly includes three magnets in spaced axial alignment with their adjacent poles being of the same polarity to cause the fields of the magnets to move laterally from between the poles through the path of the coil.

3. The geophone of claim 1 in which the magnet assembly includes a plurality of magnets in axial alignment, two pair of said magnets being spaced apart with like poles adjacent to cause the flux lines of the magnetic fields of the magnets to extend laterally from the space between the magnets and across the coil.

4. The geophone of claim 1 in which the magnet assembly includes a magnet on one side of the coil and a magnet on the other side both in axial alignment with the axis of the coil and positioned with opposite poles facing in the same direction to shape the magnetic field to increase the density of the field through which the coil travels.

5. The geophone of claim 1 in which the magnet assembly includes a magnet positioned on one side of the coil in axial alignment with the direction of travel of the coil relative to the magnet to provide a magnetic field through which the coil travels and a second magnet positioned on the other side of the coil with its poles positioned to attract the flux from the first magnet to increase the density of the magnetic flux passing through the coil.

6. A geophone comprising a permanent magnet assembly providing a magnetic field, a coil mounted for movement relative to the magnet assembly along a selected axis to produce a signal in response to the movement of the coil through the magnetic field of the magnet assembly, and magnetic means positioned for shaping the magnetic field of the permanent magnet to increase the density of the magnetic field through which the coil moves.

7. The geophone of claim 6 in which the field shaping means includes permanent magnets positioned in axial alignment with the permanent magnet assembly and on opposite sides thereof with the pole of each magnet facing a like pole of the permanent magnet to increase the density of the magnetic field of the permanent magnet that extends laterally of the axis of the magnets through the path of the coil.

8. The geophone of claim 6 in which the field shaping means includes a magnet positioned on the opposite side of the coil with its poles positioned to magnetically attract the magnetic field of the permanent magnet and cause an increase in the density of the magnetic field passing through the path of the coil.

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